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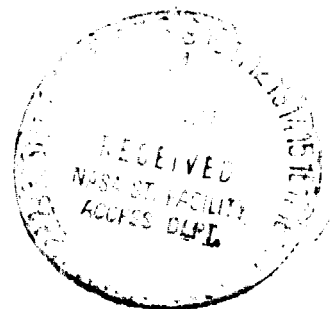
FINAL REPORT
FOR
JANTX 2N2060

JANUARY 1979

Prepared
For

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FOREWORD

This report is a summary of the work performed on NASA Contract NAS8-31944. The investigation was conducted for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville; Alabama. The Contracting Officer's Technical Representative was Mr. F. Villella.

The short-term objective of this preliminary study of transistors, diodes, and FETS is to evaluate the reliability of these discrete devices, from different manufacturers, when subjected to power and temperature step stress tests.

The long-term objective is to gain more knowledge of accelerated stress testing for use in future testing of discrete devices, as well as to determine which type of stress should be applied to a particular device or design.

This report is divided as follows: description of tests, figures, tables, and appendix.



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1.0 INTRODUCTION

DCA Reliability Laboratory, under contract NAS8-31944 for NASA/Marshall Space Flight Center, has compiled data for the purpose of evaluating the effect of power/temperature step stress when applied to a variety of semiconductor devices. This report covers the dual transistor JANTX2N2060 manufactured by Raytheon and Motorola.

A total of 48 samples from each manufacturer were submitted to the process outlined in Table 1. In addition, two control sample units were maintained for verification of the electrical parametric testing.

2.0 TEST REQUIREMENTS

2.1 Electrical

All test samples were subjected to the electrical tests outlined in Table 2 after completing the prior power/temperature step stress point. These tests were performed using the Fairchild Model 600 high-speed computer-controlled tester. Additional bench testing was also required on the devices.

2.2 Stress Circuit

The test circuit shown in Figure 1 was used to power all of the test devices during the power/temperature stress conditions. The V_{CE} was varied to obtain maximum rated power (MRP) on at least one of the devices. All the remaining devices were subjected to no less than 90 percent of maximum rated power. See Figure 1 for load resistance values and voltages.



2.3 Group I - Power Stress.

Thirty-two units, 16 from each manufacturer, were submitted to the Power Stress Process. The transistors were stressed in 500-hour steps at 50, 100, 125, 150, and 175 percent of MRP for a total of 2500 hours or until 50 percent or more of the devices failed.* Electrical measurements were performed on all specified electrical parameters after each power step. See Table 1.

2.4 Group II - Temperature Stress I

Thirty-two units, 16 from each manufacturer, were submitted to the Temperature Stress I Process. Group II was subjected to a total of 1600 hours of stress at MRP in increments of 160 hours. The temperature was increased in steps of 25°C, commencing at 75°C and terminating at 300°C or until 50 percent or more of the devices failed.* Electrical measurements were performed on all specified electrical parameters after each temperature step. See Table 1.

2.5 Group III - Temperature Stress II

Thirty-two units, 16 from each manufacturer, were submitted to the Temperature Stress II Process. Group III was subjected to a total of 112 hours of stress at MRP in increments of 16 hours. The temperature was increased in steps of 25°C, commencing at 150°C and terminating at 300°C or until 50 percent or more of the devices failed.* Electrical measurements were performed on all specified

*Conditions for failure:

- A) Open or short
- B) Leakage exceeds the maximum limit by 100 times.
- C) Other parameters exceed MIL limits by 50 percent or greater.



electrical parameters after each temperature step.
See Table 1.

3.0 DISCUSSION OF TEST RESULTS

3.1 Group I - Power Stress

3.1.1 Raytheon. The Raytheon sample lot completed the entire 2500-hour Group I testing with two catastrophic failures. The two failures occurred 150 hours into the 50 percent MRP step. Serial numbers 1904 (SIDE "A") and 1900 (side "B") failed the maximum $V_{CE(SAT)}$ limit and the minimum h_{FE} limit. Typical characteristics for this sample lot's performance (side "A") were:

- 1) The mean value for I_{CBO} changed 222.6pA from an initial mean of 421.2pA to a final mean of 198.6pA.
- 2) The mean value for $V_{CE(SAT)}$ changed 1.95mV from an initial mean of 72.69mV to a final mean of 74.64mV.
- 3) The mean value for h_{FE} changed 6.45 from an initial mean of 59.66 to a final mean of 66.11.

Typical characteristics of this sample lot's performance (side "B") were:

- 1) The mean value for I_{CBO} changed 209.5pA from an initial mean of 358.1pA to a final mean of 148.6pA.
- 2) The mean value for $V_{CE(SAT)}$ changed 2.65mV from an initial mean of 73.06mV to a final mean of 75.71mV.
- 3) The mean value for h_{FE} changed 5.64 from an initial mean of 60.74 to a final mean of 66.38.
- 4) The mean value for h_{FE} (matching) changed .0322 from an initial mean of .9838 to a final mean of 1.016.

The control units for this sample lot remained constant throughout the entire Group I testing.



3.1.2 Motorola. The Motorola sample lot completed the entire 2500-hour Group I testing with five catastrophic failures. The first three failures occurred 150 hours into the 50 percent MRP step. Serial numbers 3710 (side "A"), 3717 (side "A"), and 3708 (side "B") failed the maximum $V_{CE(SAT)}$ limit, and minimum h_{FE} limit. The next failure occurred 50 hours into the 150 percent MRP step. Serial number 3703 (side "B") failed because of excessive I_{CBO} leakage. The last failure occurred 500 hours into the 175 percent MRP step. Serial number 3705 (side "B") failed the minimum h_{FE} limit. Typical characteristics of this sample lot's performance (side "A") were:

- 1) The mean value for I_{CBO} changed 57.7pA from an initial mean of 219.4pA to a final mean of 161.7pA.
- 2) The mean value for $V_{CE(SAT)}$ changed .70mV from an initial mean of 104.9mV to a final mean of 105.6mV.
- 3) The mean value for h_{FE} changed 2.09 from an initial mean of 61.83 to a final mean of 63.92.

Typical characteristics of this sample lot's performance (side "B") were:

- 1) The mean value for I_{CBO} changed 36.7pA from an initial mean of 255.0pA to a final mean of 218.3pA.
- 2) The mean value for $V_{CE(SAT)}$ changed 58.6mV from an initial mean of 163.9mV to a final mean of 105.3mV.
- 3) The mean value for h_{FE} changed 9.48 from an initial mean of 52.34 to a final mean of 61.82.
- 4) The mean value for h_{FE} (matching) changed .161 from an initial mean of 1.183 to a final mean of 1.022.

The control units for this sample lot remained constant throughout the entire Group I testing.



3.1.3 Statistical Summary - Group I

Table 4 outlines the results of Group I - Power Stress Process for all of the specified electrical parameters and all measurement points for both Raytheon and Motorola.

3.2 Group II - Temperature Stress I

3.2.1 Raytheon. The Raytheon sample lot completed the entire 1600-hour Group II testing with a total of nine catastrophic failures. The first failure occurred 160 hours into the 200°C-temperature step. Serial number 1925 (side "A") failed the minimum h_{FE} limit. The next three failures occurred 160 hours into the 225°C-temperature step. Serial numbers 1918 (side "B") and 1920 (side "A") failed the minimum h_{FE} limit. Serial number 1921 (side "B") failed the maximum $V_{CE(SAT)}$ limit and minimum h_{FE} limit. The next failure occurred 160 hours into the 250°C-temperature step. Serial number 1924 (side "A") failed the minimum h_{FE} limit. The next failure occurred 160 hours into the 275°C-temperature step. Serial number 1915 failed the maximum h_{FE} (matching) limit. The last three failures occurred 160 hours into the 300°C-temperature step. Serial numbers 1914 (side "A"), 1916 (side "B"), and 1926 (side "B") failed the minimum h_{FE} limit. Typical characteristics of this sample lot's performance (side "A") were:

- 1) The mean value for I_{CBO} changed 25.8pA from an initial mean of 140.6pA to a final mean of 166.4pA.
- 2) The mean value for $V_{CE(SAT)}$ changed 16.6mV from an initial mean of 73.13mV to a final mean of 89.73mV.
- 3) The mean value for h_{FE} changed 26.95 from an initial mean of 65.1 to a final mean of 38.15.

Typical characteristics of this sample lot's performance (side "B") were:

- 1) The mean value for I_{CBO} changed 145.98pA from an



initial mean of 63.12pA to a final mean of 209.1pA.

- 2) The mean value for $V_{CE(SAT)}$ changed 5.28mV from an initial mean of 72.63mV to a final mean of 77.91mV.
- 3) The mean value for h_{FE} changed 23.31 from an initial mean of 64.29 to a final mean of 40.98.
- 4) The mean value for h_{FE} (matching) changed .581 from an initial mean of 1.008 to a final mean of 1.589.

The control units for this sample lot remained constant throughout the entire Group II testing.

3.2.2 Motorola. The Motorola sample lot completed the entire 1600-hour Group II testing with one catastrophic failure. The failure occurred 160 hours into the 200°C-temperature step. Serial number 3723 failed the minimum h_{FE} limit. Typical characteristics of this sample lot's performance (side "A") were:

- 1) The mean value for I_{CBO} changed 30.65pA from an initial mean of 93.75 pA to a final mean of 124.4pA.
- 2) The mean value for $V_{CE(SAT)}$ changed 18.9mV from an initial mean of 107.0mV to a final mean of 125.9mV.
- 3) The mean value for h_{FE} changed 4.92 from an initial mean of 63.73 to a final mean of 58.81.

Typical characteristics of this sample lot's performance (side "B") were:

- 1) The mean value for I_{CBO} changed 100.58pA from an initial mean of 35.62pA to a final mean of 136.2pA.
- 2) The mean value for $V_{CE(SAT)}$ changed 18.6mV from an initial mean of 106.3mV to a final mean of 124.9mV.
- 3) The mean value for h_{FE} changed 5.13 from an initial mean of 53.59 to a final mean of 58.72.
- 4) The mean value for h_{FE} (matching) changed .186 from an initial mean of 1.189 to a final mean of 1.003.



The control units for this sample lot remained constant throughout the entire Group II testing.

3.2.3 Statistical Summary - Group II

Table 5 outlines the results of Group II - Temperature Stress I testing for all of the specified electrical parameters and all of the measurement points pertaining to both Raytheon and Motorola.

3.3 Group III - Temperature Stress II

3.3.1 Raytheon. The Raytheon sample lot completed the entire 112-hour Group III testing with a total of three catastrophic failures. The first failure occurred 16 hours into the 150°C-temperature step. Serial number 1939 (side "A") failed the minimum h_{FE} limit. The next failure occurred 16 hours into the 175°C-temperature step. Serial number 1934 failed the maximum h_{FE} (matching) unit. The last failure occurred 16 hours into the 300°C-temperature step. Serial number 1937 failed the maximum h_{FE} (matching) limit. Typical characteristics of this sample lot's performance (side "A") were:

- 1) The mean value for I_{CBO} changed 9.001nA from an initial mean of 314.0pA to a final mean of 9.315nA.
- 2) The mean value for $V_{CE(SAT)}$ changed .27mV from an initial mean of 72.13mV to a final mean of 72.4mV.
- 3) The mean value for h_{FE} changed 8.44 from an initial mean of 60.65 to a final mean of 69.09.

Typical characteristics of this sample lot's performance (side "B") were:

- 1) The mean value for I_{CBO} changed 1.513nA from an initial mean of 180.0pA to a final mean of 1.693nA.



- 2) The mean value for $V_{CE(SAT)}$ changed 36.10mV from an initial mean of 72.4mV to a final mean of 108.5mV.
- 3) The mean value for h_{FE} changed 3.60 from an initial mean of 59.55 to a final mean of 63.15.
- 4) The mean value for h_{FE} (matching) changed 1.005 from an initial mean of 1.020 to a final mean of 2.025.

The control units for this sample lot remained constant throughout the entire Group III testing.

3.3.2 Motorola. The Motorola sample lot completed the entire 112-hour Group III testing with no catastrophic failures. Typical characteristics of this sample lot's performance (side "A") were:

- 1) The mean value for I_{CBO} changed 1.33pA from an initial mean of 48.67pA to a final mean of 50.0pA.
- 2) The mean value for $V_{CE(SAT)}$ changed 3.30mV from an initial mean of 103.0mV to a final mean of 106.3mV.
- 3) The mean value for h_{FE} changed 8.30 from an initial mean of 60.39 to a final mean of 68.69.

Typical characteristics of this sample lot's performance (side "B") were:

- 1) The mean value for I_{CBO} changed 14.67pA from an initial mean of 38.0pA to a final mean of 52.67pA.
- 2) The mean value for $V_{CE(SAT)}$ changed 4.40mV from an initial mean of 102.7mV to a final mean of 107.1mV.
- 3) The mean value for h_{FE} changed 9.34 from an initial mean of 58.57 to a final mean of 67.91.
- 4) The mean value for h_{FE} (matching) changed .011 from an initial mean of 1.028 to a final mean of 1.017.

The control units for this sample lot remained constant throughout the entire Group III testing.



3.3.3 Statistical Summary - Group II

Table 6 outlines the results of Group III - Temperature Stress II testing for each of the specified electrical parameters and all measurement points for both Raytheon and Motorola.

4.0 FINAL DATA SUMMARY

Table 7 statistically summarizes the change in the mean value from the zero-hour data to the final data. The graphs of Figures 2 and 4 plot the cumulative percent failures versus the temperature stress level for Group II - Temperature Stress I, and Group III - Temperature Stress II. The graphs of Figures 3 and 5 plot the time step for Group II (160 hours) and Group III (16 hours) versus the temperatures T_1 and T_2 calculated from Figures 2 and 4. Tables 8 and 9 summarize the failures encountered for all three stress groups. The failures are separated into two categories: catastrophic failures in Table 8 and parametric failures in Table 9. The data from Table 8 was used as a source for the graphs in 3 and 5 respectively. Junction temperature is plotted on an inverse hyperbolic scale.

5.0 CONCLUSIONS

The Motorola sample lot showed signs of weakness in the Group I testing, while the Raytheon lot lost a majority of its devices in the Group II testing.

The Motorola devices in the Group I testing experienced a decline in h_{FE} , while the collector-base leakages remained within specification limits. Such a loss of h_{FE} without any evidence of surface leakage or low breakdown voltage suggests a change in emitter efficiency.



The migration of gold or other impurities has possibly continued under the influence of extreme high-power operation with consequent loss of h_{FE} .

All of the failures in the Group II testing for Raytheon experienced some marked loss of h_{FE} . There is no significant bulk of surface leakage on these parts. This implies that the h_{FE} fall-off is due only to a loss of emitter efficiency. The loss of injection efficiency in turn is due to the migration of gold and intermetallics under the influence of heat and bias, with a consequent loss of bulk silicon lifetime.

A plot showing cumulative failure distribution for Groups II and III testing was drawn for the Raytheon sample lot (Figures 2 and 3) but a plot for the Motorola sample lot could not be drawn due to an insufficient number of failures in the Group II testing and an absence of failures in the Group III testing. Figures 2 and 3 display the data for the Raytheon sample lot used to calculate an activation energy of 1.29eV.

A broken circle around a marked point on the graph indicates a freak failure not calculated as part of the regression line. A solid circle around a marked point indicates an isolated failure point. The regression line was drawn using the least square method.



The activation energy was calculated from the formula:

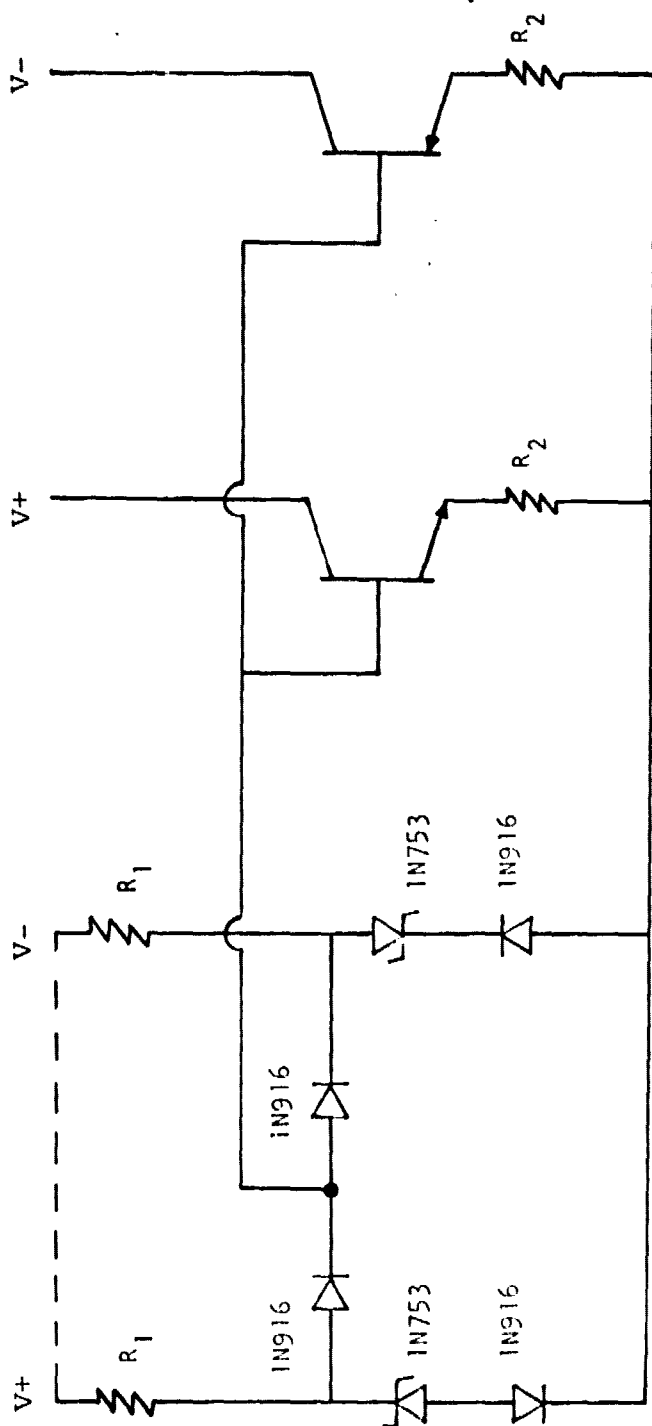
$$E = \left[\ln \left(\frac{t_1}{t_2} \right) \right] \left[\frac{8.63 \times 10^{-5} \text{ eV/}^\circ\text{K}}{\left(\frac{1}{T_1 + 273} \right) - \left(\frac{1}{T_2 + 273} \right)} \right] \text{ eV}$$

Where: t_1 = step of Group II - Temp Stress I = 160 hrs.

t_2 = step of Group III - Temp Stress II = 16 hrs.

T_1 = temperature in $^\circ\text{C}$ of 16% failure for Group II.

T_2 = temperature in $^\circ\text{C}$ of 16% failure for Group III.



NOTES: $R_1 = 800 \pm 5\%, 2W$. $R_2 = 562 \Omega \pm 1\%, \frac{1}{4}W$

Use V+ for NPN Transistors; Use V- for PNP Transistors.

FIGURE 1
Power/Temperature Stress Circuit
JANTX2N2060



NOTE
FOR TABLES
4 THROUGH 7

The minimum/maximum initial and final data generally have an absolute accuracy of $\pm 1\%$ of the reading and \pm one digit except for readings greater than 9.99mA which have an absolute accuracy of $\pm 2\%$ of the reading and \pm one digit. The data also has a resolution for four digits. The standard deviations, means, delta means, and average means are, therefore, valid indicators of trends over time and temperature, excepting the minor statistical computer error of supplying a constant number of significant digits.



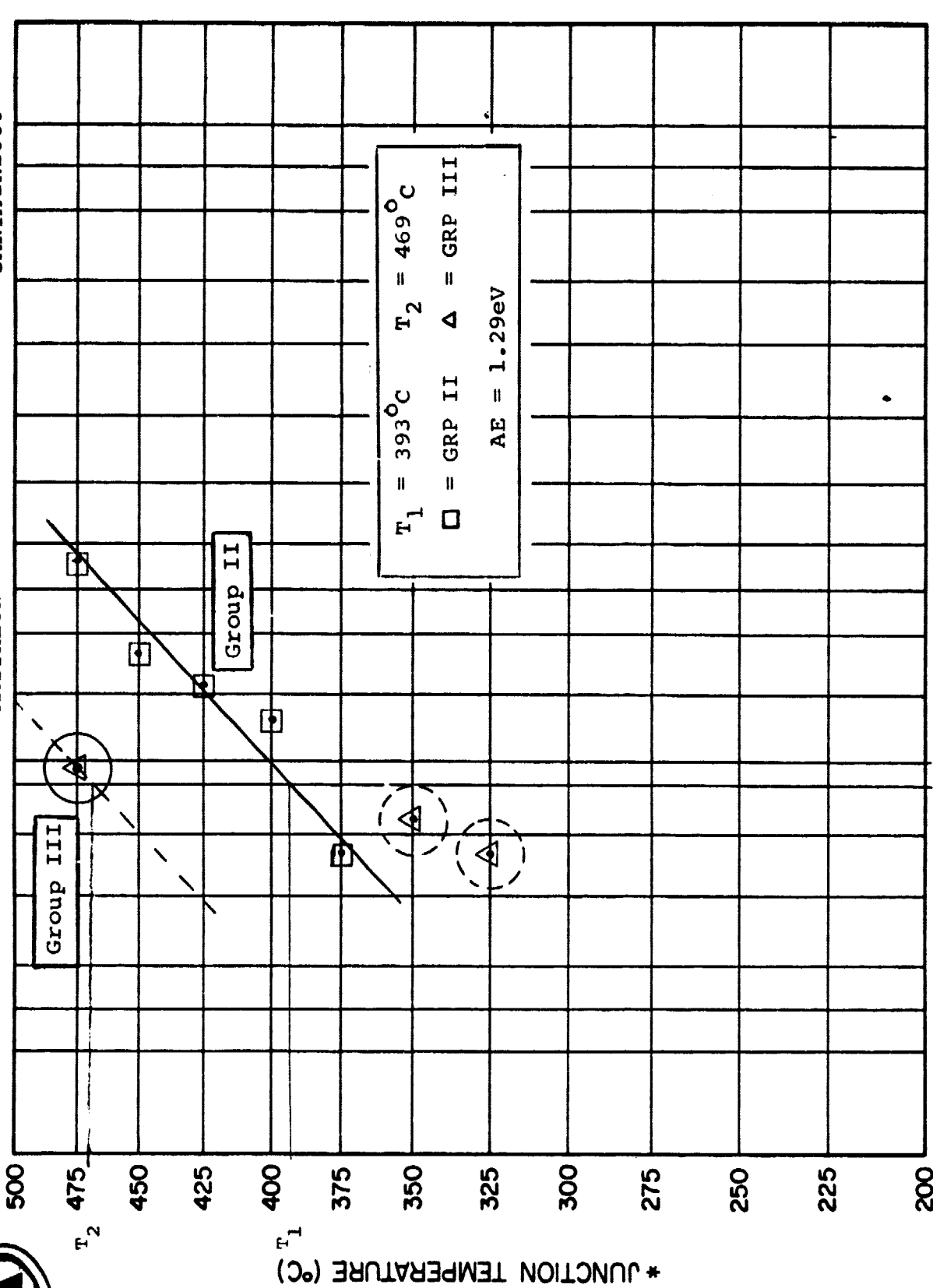
RAYTHEON

JANTX 2N2060

JANTX2N2060

*NOTE

$$T_J \approx T_A + 175^\circ\text{C}$$



Cumulative Percent Failures Versus Junction Temperature, Raytheon

FIGURE 2

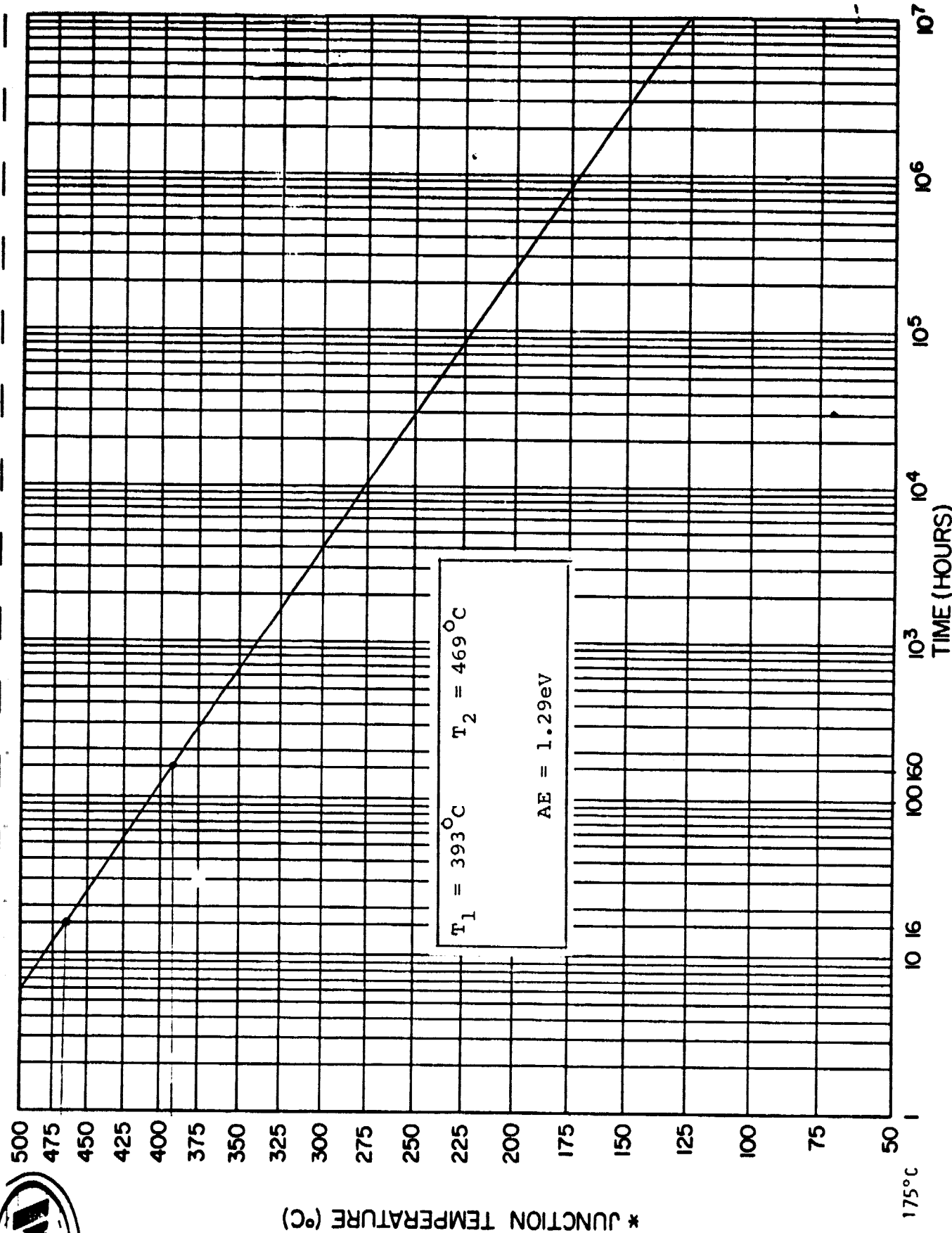


FIGURE 3

Time Steps Versus Junction Temperature, Raytheon

*NOTE

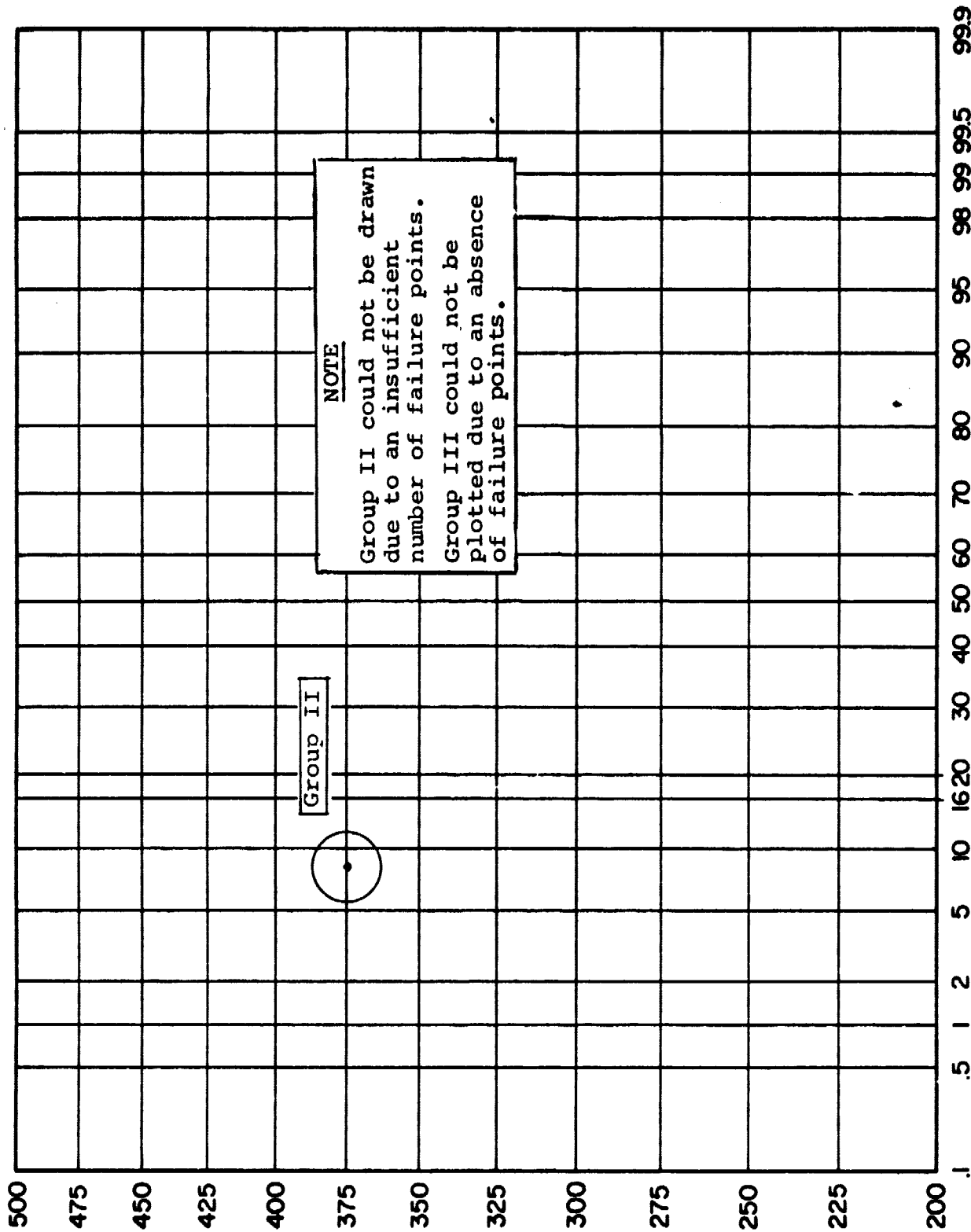
$$T_J \approx T_A + 175^{\circ}\text{C}$$



MOTOROLA

JANTX2N2060

JANTX2N2060



* JUNCTION TEMPERATURE (°C)

*NOTE

$$T_J \approx T_A + 175^\circ\text{C}$$

FIGURE 4
Cumulative Percent Failures Versus Junction Temperature, Motorola

J X2N 0

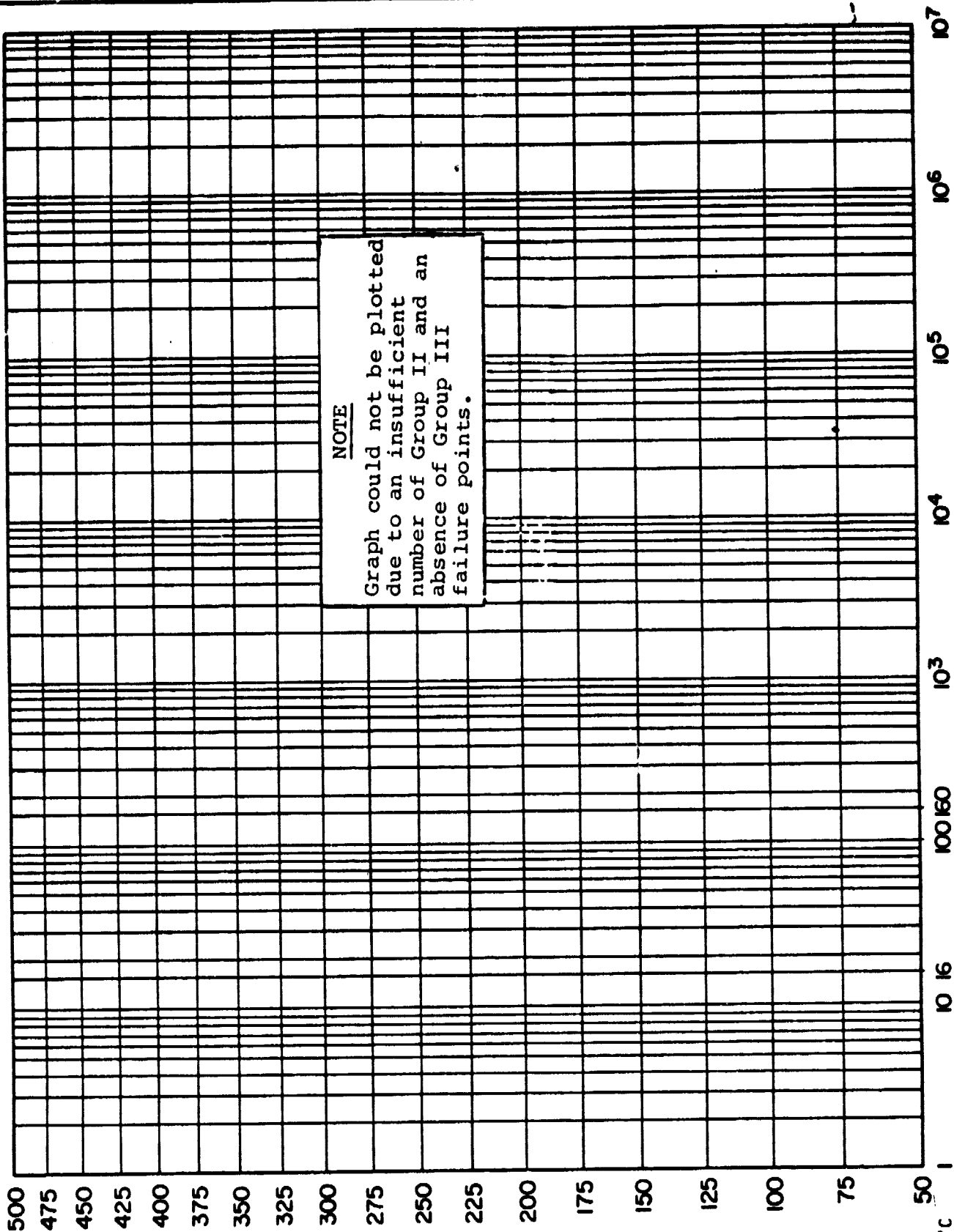
M ROI



* JUNCTION TEMPERATURE (°C)

*NOTE

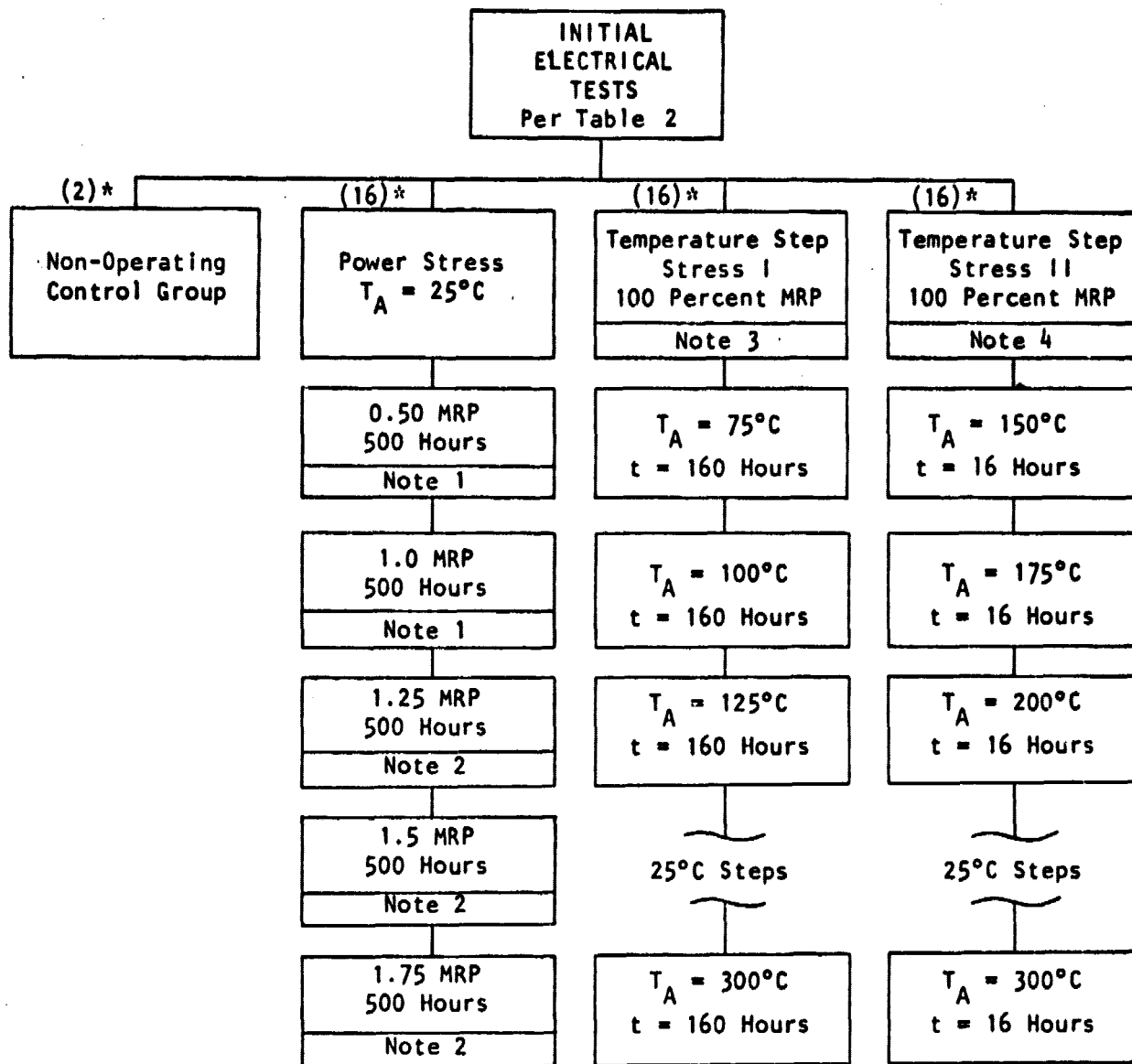
$$T_J \approx T_A + 175^\circ\text{C}$$



TIME (HOURS)

FIGURE 5

Time Steps Versus Junction Temperature, Motorola

TABLE 1
TEST FLOW DIAGRAM

*Quantity per manufacturer (RAYTHEON & MOTOROLA)

NOTES:

- 1) Electrical measurements per Table 2 were made at 50, 150, 250 and 500 hours.
- 2) Electrical measurements per Table 2 were made at 10, 25, 50, 150, 250 and 500 hours.
- 3) Electrical measurements per Table 2 were made at the end of each 160 hours.
- 4) Electrical measurements per Table 2 were made at the end of each 16 hours.



TABLE 2
PARAMETERS AND TEST CONDITIONS

PARAMETER	CONDITIONS	SPEC. LIMIT		CAT. LIMIT		UNITS
		MIN	MAX	MIN	MAX	
I_{CBO}	@ $V_{CB} = 80V$	-	2	-	200	nA
h_{FE} matching	@ $V_{CE} = 5V$ & $I_C = 100\mu A$.9	1.1	.45	1.65	-
$V_{CE(SAT)}$	@ $I_C = 50mA$ & $I_B = 5mA$	-	1.2	-	1.8	V
h_{FE}	@ $V_{CE} = 5V$ & $I_C = 100\mu A$	30	90	15	135	-

NOTES:

In addition, any open or short shall be considered catastrophic.

TABLE 3
POWER STRESS BURN-IN CONDITIONS

$I_E = 10.0mA$	
$V_{CE} =$	PERCENT P_D
12.5V	50
25.0V	100
31.2V	125
37.5V	150
43.7V	175



TABLE 4
GROUP I - POWER STRESS DATA SUMMARY, SIDE A

PARAMETER	$I_{CBO} = 2nA(MAX)$		$V_{CE(SAT)} = 1.2V(MAX)$		$h_{FE1} = 30 (MIN) \quad 90 (MAX)$	
CONDITIONS AND LIMIT	$@V_{CB} = 80V$		$@I_C = 50mA \text{ \& } I_B = 5mA$		$@V_{CE} = 5V \text{ \& } I_C = 100\mu A$	
IDENTIFICATION	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA
INITIAL DATA						
MIN VALUE	190.0 pA	170.0 pA	68.0 mV	100.0 mV	48.80	47.40
MAX VALUE	1130.9 pA	320.0 pA	78.0 mV	119.0 mV	69.40	81.30
MEAN	421.2 pA	219.4 pA	72.69 mV	104.9 mV	59.66	61.83
STD DEV	300.1 pA	45.34 pA	2.709 mV	5.056 mV	5.662	8.561
INTERIM DATA						
POWER 50 TO 125%						
Δ MEAN VALUE						
50% POWER						
50 HRS	37.5 pA	-24.4 pA	-.31 mV	.40 mV	-.80	-.09
150 HRS	-168.7 pA	-208.15 pA	619.71 mV*	1.24 V*	4.21*	-7.93*
250 HRS	-210.5 pA	-207.86 pA	-.12 mV	-.70 mV	-.55	1.76
500 HRS	-28.3 pA	-114.9 pA	.45 mV	-.40 mV	-.53	1.19
100% POWER						
550 HRS	-54.1 pA	-114.7 pA	.88 mV	-.20 mV	1.11	1.49
650 HRS	-92.6 pA	159.8 pA	.95 mV	-.30 mV	1.33	1.13
750 HRS	-115.5 pA	-108.6 pA	.74 mV	-.10 mV	.72	1.35
1000 HRS	-125.5 pA	-127.86 pA	3.52 mV	2.3 mV	1.75	1.60
125% POWER						
1010 HRS	-126.2 pA	-74.8 pA	3.88 mV	2.7 mV	.75	.89
1025 HRS	-108.3 pA	-96.3 pA	3.88 mV	2.6 mV	.35	.19
1050 HRS	-111.2 pA	-89.4 pA	2.17 mV	1.0 mV	.28	.17
1150 HRS	-139.8 pA	-100.2 pA	4.17 mV	2.7 mV	.58	.75
1250 HRS	-112.6 pA	-74.0 pA	2.24 mV	-.90 mV	-.09	1.02
1500 HRS	-179.8 pA	72.6 pA	2.74 mV	1.20 mV	.18	-.26

(continued on second sheet)

TABLE 4 (Cont'd)
GROUP I — POWER STRESS DATA SUMMARY, SIDE A

Page 2 of 2

(continued from first sheet)

PARAMETER	$I_{CB0} = 2nA \text{ (MAX)}$		$V_{CE(SAT)} = 1.2V \text{ (MAX)}$		$h_{FE1} = 30 \text{ (MIN)} \text{ } 50 \text{ (MAX)}$	
CONDITIONS AND LIMITS	$\theta V_{CB} = 80V$		$\theta I_C 50mA \text{ \& } I_B = 5mA$		$\theta V_{CE} = 5V \text{ \& } I_{CE} = 100\mu A$	
IDENTIFICATION	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA
INITIAL DATA						
MIN VALUE	190.0 pA	170.0 pA	68.0 mV	100.0 mV	48.80	47.40
MAX VALUE	1130.0 pA	320.0 pA	78.0 mV	119.0 mV	69.40	81.30
MEAN	421.2 pA	219.4 pA	72.69 mV	104.9 mV	59.66	61.83
STD DEV	320.1 pA	45.34 pA	2.709 mV	5.056 mV	5.662	8.561
INTERIM DATA						
POWER 150 TO 175% Δ MEAN VALUE						
150% POWER						
1510 HRS	-44.8 pA	264.4 pA	1.88 mV	.30 mV	-.91	.07
1525 HRS	-160.5 pA	13.43 nA*	2.95 mV	1.60 mV	.18	1.22
1550 HRS	-156.2 pA	6.48 nA*	2.38 mV	.80 mV	-.62	.41
1650 HRS	-124.8 pA	-90.2 pA	2.17 mV	1.30 mV	.18	2.59
1750 HRS	-71.2 pA	-41.9 pA	2.10 mV	1.60 mV	1.13	3.54
2000 HRS	-114.1 pA	-81.1 pA	1.38 mV	-.20 mV	.88	2.60
175% POWER						
2010 HRS	-184.8 pA	-76.1 pA	1.88 mV	.40 mV	2.27	3.44
2025 HRS	-221.2 pA	-87.7 pA	1.95 mV	.60 mV	2.85	3.71
2050 HRS	-147.6 pA	-94.4 pA	1.45 mV	-.90 mV	1.90	3.21
2150 HRS	-192.6 pA	-84.4 pA	1.52 mV	-.40 mV	4.16	4.94
2250 HRS	-180.5 pA	-96.9 pA	1.45 mV	-.50 mV	2.90	4.31
2500 HRS	-222.6 pA	-57.7 pA	1.95 mV	.70 mV	6.45	2.09
FINAL DATA						
MIN VALUE	80.0 pA	90.0 pA	70.0 mV	99.0 mV	50.10	8.3
MAX VALUE	510.0 pA	450.0 pA	83.0 mV	118.0 mV	78.40	92.80
MEAN	198.6 pA	161.7 pA	74.64 mV	105.6 mV	66.11	63.92
STD DEV	133.0 pA	94.24 pA	3.847 mV	5.171 mV	8.213	19.25

NOTE: Catastrophic Rejects removed from data after this point.

TABLE 4
GROUP I - POWER STRESS DATA SUMMARY, SIDE B
Page 1 of 2

PARAMETER	$I_{CB0} = 2\text{mA (MAX)}$		$V_{CE(SAT)} = 1.2\text{V (MAX)}$		$h_{FE2} = 30\text{ (MIN)} 90\text{ (MAX)}$		$h_{FE1}/h_{FE2} = .9\text{ (MIN)} 1.1\text{ (MAX)}$	
CONDITIONS AND LIMIT	$V_{CB} = 80\text{V}$		$@ I_C = 50\text{mA} \ \& \ I_B = 5\text{mA}$		$@ V_{CE} = 5\text{V} \ \& \ I_C = 100\mu\text{A}$		$@ V_{CE} = 5\text{V} \ \& \ I_C = 100\mu\text{A}$	
IDENTIFICATION	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA
INITIAL DATA								
MIN VALUE	180.0 pA	160.0 pA	69.0 mV	99.0 mV	52.10	43.00	.890	.940
MAX VALUE	1.210 pA	750.0 pA	81.0 mV	1.05 V	70.70	70.10	1.190	1.440
MEAN	358.1 pA	255.0 pA	73.06 mV	163.9 mV	60.74	52.34	.9838	1.183
STD DEV	257.8 pA	163.9 pA	3.363 mV	228.9 mV	5.655	6.287	.07825	.0146
INTERIM DATA								
POWER 50 TO 125%								
Δ MEAN VALUE								
50% POWER								
50 HRS	38.1 pA	-85.0 pA	11.88 mV	6.1 mV	-.64	2.43	-.0025	56.157
150 HRS	-232.5 pA	-171.47 pA	619.54 mV*	521.3 mV*	4.78*	-1.48	2.106 *	-.091
250 HRS	-273.1 pA	-221.92 pA	.23 mV	-60.8 mV	-.39	4.20	-.0017	-.055
500 HRS	-136.0 pA	-53.5 pA	.94 mV	-59.4 mV	-.11	5.62	-.0067	-.098
100% POWER								
550 HRS	-146.7 pA	-71.9 pA	1.51 mV	-59.6 mV	1.21	5.82	-.0017	-.098
650 HRS	-185.2 pA	-83.5 pA	1.37 mV	-59.4 mV	1.32	5.94	-.0002	-.103
750 HRS	-183.8 pA	-89.6 pA	1.30 mV	-59.7 mV	.82	5.92	-.0017	-.099
1000 HRS	-172.4 pA	-78.8 pA	4.23 mV	-57.0 mV	1.63	6.43	.0026	-.106
125% POWER								
1010 HRS	-158.1 pA	-61.9 pA	4.30 mV	-57.0 mV	.42	5.59	.0069	-.102
1025 HRS	-178.1 pA	-71.2 pA	4.23 mV	-56.5 mV	.26	5.21	.0005	-.108
1050 HRS	-162.4 pA	-59.6 pA	4.15 mV	-56.4 mV	.34	5.53	-.0009	-.115
1150 HRS	-156.0 pA	-73.5 pA	4.87 mV	-56.0 mV	.42	6.08	.0019	-.111
1250 HRS	-183.1 pA	-74.2 pA	2.80 mV	-58.8 mV	.24	6.33	-.0038	-.112
1500 HRS	-178.1 pA	-73.5 pA	3.30 mV	-57.9 mV	-.06	6.49	.0041	-.116

(continued on second sheet)



TABLE 4 (Cont'd)
- POWER STRESS DATA SUMMARY, SIDE B

Page 2 of 2

PARAMETER	I _{CBO} = 2nA (MAX)		V _{CE(SAT)} = 1.2V (MAX)		h _{FE2} = 30(MIN) 90(MAX)		h _{FE1} /h _{FE2} = 5(MIN) 1.1(MAX)	
	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA
CONDITIONS AND LIMITS	@V _{CB} = 80V		@I _C = 50mA & I _B = 5mA		@V _{CE} = 5V & I _C = 100μA		@V _{CE} = 5V & I _C = 100μA	
IDENTIFICATION								
INITIAL DATA								
MIN VALUE	180.0 pA	160.0 pA	69.0 mV	99.0 mV	52.10	43.00	.890	.940
MAX VALUE	1.210 pA	750.0 pA	81.0 mV	1.05 V	70.70	70.10	1.190	1.440
MEAN	358.1 pA	255.0 pA	73.06 mV	153.9 mV	60.74	52.34	.9838	1.183
STD DEV	257.8 pA	163.9 pA	3.363 mV	228.9 mV	5.655	6.287	.07825	.1046
INTERIM DATA								
POWER 150 TO 175%								
Δ MEAN VALUE								
150% POWER								
1510 HRS	-155.2 pA	-69.6 pA	2.65 mV	-59.4 mV	-55	5.66	-.0038	-.118
1525 HRS	-191.7 pA	-77.3 pA	3.58 mV	-57.6 mV	.37	7.11	.0041	-.128
1550 HRS	-198.1 pA	-99.5 pA	3.30 mV	-58.4 mV	-.36	6.31	-.0067	-.118
1650 HRS	-183.1 pA	-63.3 pA	3.87 mV	-57.3 mV	.20	7.05	-.0038	-.107
1750 HRS	-160.2 pA	-.8 pA	3.01 mV	-58.3 mV	1.15	8.70	-.0059	-.111
2000 HRS	-148.1 pA	-60.8 pA	2.30 mV	-59.3 mV	.57	8.43	.0062	-.118
175% POWER								
2010 HRS	-228.1 pA	-79.2 pA	2.65 mV	-59.4 mV	2.25	9.27	.0148	-.123
2025 HRS	-225.2 pA	-86.7 pA	2.51 mV	-59.0 mV	1.97	9.68	-.0052	-.125
2050 HRS	-184.5 pA	-72.5 pA	2.51 mV	-59.1 mV	2.07	9.62	.0272	-.133
2150 HRS	-198.1 pA	-48.3 pA	2.51 mV	-59.1 mV	3.57	11.39	.0098	-.134
2250 HRS	-186.0 pA	-78.3 pA	2.15 mV	-59.5 mV	2.49	10.85	-.0017	-.133
2500 HRS	-209.5 pA	-36.7 pA	2.65 mV	-58.6 mV	5.64	9.48	.0322	-.161
FINAL DATA								
MIN VALUE	80.0 pA	100.0 pA	69.0 mV	99.0 mV	50.90	10.10	.940	.820
MAX VALUE	380.0 pA	540.0 pA	88.0 mV	121.0 mV	78.00	87.80	1.150	1.100
MEAN	148.6 pA	218.3 pA	75.71 mV	105.3 mV	66.38	61.82	1.016	1.022
STD DEV	78.9 pA	148.3 pA	5.417 mV	6.093 mV	7.718	17.82	.05447	.0747

NOTE: Catastrophic Rejects removed from data after this point.

TABLE 5

GROUP II TEMP STRESS I DATA SUMMARY, SIDE A (160 HR STEPS)

PARAMETERS	$I_{CB0} = 2nA$ (MAX)		$V_{CE}(SA^*) = 1.2V$ (MAX)		$h_{FE1} = 30(MIN)$ 90(MAX)	
CONDITIONS AND LIMITS	$@V_{CB} + 80V$		$@I_C = 50nA$ & $I_B = 5mA$		$@V_{CE} = 5V$ & $I_C = 100\mu A$	
IDENTIFICATION	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA
INITIAL DATA						
MIN VALUE	0.00 A	0.00 A	70.0 mV	98.0 mV	57.9	43.00
MAX VALUE	1.03 nA	930.0 pA	78.0 mV	120.9 mV	75.9	82.40
MEAN	140.6 pA	93.75 pA	73.13 mV	107.0 mV	65.1	63.73
STD DEV	266.5 pA	235.1 pA	2.781 mV	6.403 mV	5.405	10.78
INTERIM DATA (INITIAL TO FINAL)						
Δ MEAN VALUE						
TOTAL HRS						
TEMP (T_A)						
160	58.8 pA	14.25 pA	1.93 mV	1.00 mV	-.79	.13
320	166.3 pA	86.25 pA	2.87 mV	2.00 mV	-.68	-.09
480	495.6 pA	25.65 pA	1.81 mV	.10 mV	-1.90	.27
640	437.5 pA	585.65 pA	7.87 mV	1.40 mV	2.32	3.40
800	795.0 pA	73.75 pA	54.97 mV	1.30 mV	2.52	3.09
960	256.3 pA	56.85 pA	83.67 mV	3.60 mV	1.33	4.42
1120	8.461 nA*	97.45 pA	51.57 mV	5.20 mV	-10.44	4.20
1280	408.1 pA	68.15 pA	1.273 V	10.30 mV	-22.48	3.08
1440	1.504 nA*	46.85 pA	686.47 mV*	13.90 mV	-25.15	-2.04
1600	25.8 pA	30.65 pA	16.60 mV	18.90 mV	26.95*	-4.92
FINAL DATA						
TEMP (T_A)	300°C	300°C	300°C	300°C	300°C	300°C
FINAL DATA						
TEMP (T_A)						
MIN VALUE	80.0 pA	60.0 pA	73.0 mV	112.0 mV	2.60	41.20
MAX VALUE	430.0 pA	390.0 pA	226.0 mV	171.0 mV	67.20	77.60
MEAN	166.4 pA	124.4 pA	89.73 mV	125.9 mV	38.15	58.81
STD DEV	105.8 pA	80.85 pA	43.12 mV	13.15 mV	22.16	10.02

* CATASTROPHIC REJECT(S) REMOVED AFTER THIS POINT.

TABLE 5

PARAMETERS		GROUP II		TEMP STRESS I		DATA SUMMARY SIDE B		(160 HR STEPS)	
		$I_{CB0} = 2nA$ (MAX)		$V_{CE}(SAT) = 1.2V$ (MAX)		$h_{FE2} = 30$ (MIN)		$h_{FE1}/h_{FE2} = .9$ (MIN)	
CONDITIONS AND LIMITS		$@V_{CB} = 80V$		$@I_C = 50mA \text{ \& } I_B = 5mA$		$@V_{CE} = 5V \text{ \& } I_C = 100\mu A$		$@V_{CE} = 5V \text{ \& } I_C = 100\mu A$	
IDENTIFICATION									
INITIAL DATA									
MIN VALUE		RAYTHEON		MOTOROLA		RAYTHEON		MOTOROLA	
MAX VALUE		RAYTHEON		MOTOROLA		RAYTHEON		MOTOROLA	
MEAN		RAYTHEON		MOTOROLA		RAYTHEON		MOTOROLA	
STD DEV		RAYTHEON		MOTOROLA		RAYTHEON		MOTOROLA	
INTERIM DATA									
(INITIAL TO FINAL)									
Δ MEAN VALUE									
TOTAL HRS		TEMP (T_A)							
160		75°C							
320		100°C							
480		125°C							
640		150°C							
800		175°C							
960		200°C							
1120		225°C							
1280		250°C							
1440		275°C							
1600		300°C							
FINAL DATA									
FINAL TEMP (T_A)		300°C		300°C		300°C		300°C	
MIN VALUE		80.0 pA		80.0 pA		114.0 mV		41.50	
MAX VALUE		660.0 pA		360.0 pA		157.0 mV		76.70	
MEAN		209.1 pA		136.2 pA		124.9 mV		58.72	
STD DEV		191.9 pA		79.36 pA		10.29 mV		9.930	

* CATASTROPHIC REJECT(S) REMOVED FROM DATA AFTER THIS POINT.

TABLE 6
GROUP III TEMP STRESS II DATA SUMMARY, SIDE A (16 HR STEPS)

PARAMETERS	$I_{CBQ} = 2nA$ (MAX)		$V_{CE}(SAT) = 1.2V$ (MAX)		$h_{FE1} = 30$ (MIN) 90 (MAX)	
CONDITIONS AND LIMITS	$@V_{CB} = 80V$		$@I_C = 50mA \text{ \& } I_B = 5mA$		$@V_{CE} = 5V \text{ \& } I_C = 100\mu A$	
IDENTIFICATION	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA
INITIAL DATA						
MIN VALUE	0.00 A	0.00 A	68.0 mV	97.0 mV	54.00	42.80
MAX VALUE	1.96 nA	520.0 pA	76.0 mV	111.0 mV	67.40	83.80
MEAN	314.0 pA	48.67 pA	72.13 mV	103.0 mV	60.65	60.39
STD DEV	532.5 pA	134.50 pA	2.526 mV	4.05 mV	3.733	12.82
INTERIM DATA (INITIAL TO FINAL)						
Δ MEAN VALUE						
TOTAL HRS						
TEMP (T_A)						
16	780.0 pA	-6.67 pA	-.33 mV	-.90 mV	1.50	.04
32	829.0 pA	-2.00 pA	-.53 mV	-1.00 mV	3.12	1.32
48	586.0 pA	12.66 pA	-.20 mV	.70 mV	5.22	4.89
64	888.0 pA	-4.00 pA	-.86 mV	.40 mV	8.91	6.36
80	1.121 nA	-2.00 pA	-.86 mV	1.10 mV	9.14	7.42
96	1.621 nA*	-2.00 pA	-.66 mV	2.10 mV	9.32	9.58
120	9.001 nA*	1.33 pA	.27 mV	3.30 mV	8.44	8.30
FINAL DATA						
FINAL TEMP (T_A)						
MIN VALUE	0.00 A	0.00 A	68.0 mV	99.0 mV	36.20	52.00
MAX VALUE	560.0 pA	560.0 pA	79.0 mV	115.0 mV	85.80	93.40
MEAN	.315 nA	50.0 pA	72.4 mV	106.3 mV	69.09	68.69
STD DEV	24.50 nA	144.3 pA	3.20 mV	4.419 mV	11.33	12.93

* CATASTROPHIC REJECT(S) REMOVED FROM DATA AFTER THIS POINT.

TABLE 6

GROUP III TEMP STRESS II DATA SUMMARY, SIDE B (16 HR STEPS)

PARAMETERS	$I_{CB0} = 2nA$ (MAX)		$V_{CE}(SAT) = 1.2V$		$h_{FE2} = 30(MIN)$ 90 (MAX)		$h_{FE1} h_{FE2} = .9(MIN) 1.1(MAX)$	
CONDITIONS AND LIMITS	$@V_{CB} = 80V$		$@I_C = 50mA \text{ \& } I_B = 5mA$		$@V_{CE} = 5V \text{ \& } I_C = 100\mu A$		$@V_{CE} = 5V \text{ \& } I_C = 100\mu A$	
IDENTIFICATION								
INITIAL DATA	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA
MIN VALUE	0.00 A	0.00 A	68.0 mV	97.0 mV	54.60	41.20	.920	.960
MAX VALUE	1.40 nA	470.0 pA	77.0 mV	110.0 mV	66.70	78.80	1.200	1.100
MEAN	180.0 pA	38.0 pA	72.4 mV	102.7 mV	59.55	58.57	1.020	1.028
STD DEV	368.0 pA	116.6 pA	2.752 mV	4.464 mV	3.253	11.36	.06747	.03487
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE								
TOTAL HRS	TEMP (T_A)							
16	150°C							
32	175°C							
48	200°C							
64	225°C							
80	250°C							
96	275°C							
112	300°C							
236.0 pA	0.00 A	3.33 pA	.07 mV	-0.00 mV	1.70	-1.20	.023	.023
352.0 pA	1.40 nA	-.67 pA	-.33 mV	-.20 mV	2.70	-.16	.027	.025
249.3 pA	180.0 pA	65.60 pA	.53 mV	.90 mV	4.06	3.85	.109	.029
440.0 pA	368.0 pA	66.10 pA	.33 mV	1.40 mV	6.48	6.30	.344	.002
685.3 pA	1.40 nA	66.50 pA	.67 mV	1.80 mV	6.34	6.72	.523	.013
661.3 pA	1.693 nA	40.00 pA	17.33 mV	3.00 mV	6.08	10.70	.631	-.019
1.513 nA*	2.689 nA	14.67 pA	36.10 mV*	4.40 mV	3.60	9.34	1.005 *	.011
FINAL DATA								
FINAL TEMP (T_A)	300°C		300°C		300°C		300°C	
MIN VALUE	0.00 A	0.00 A	69.0 mV	101.0 mV	5.00	53.20	.780	.960
MAX VALUE	8.610 nA	680.0 pA	473.0 mV	117.0 mV	80.20	90.50	15.58	1.110
MEAN	1.693 nA	52.67 pA	108.5 mV	107.1 mV	63.15	67.91	2.025	1.017
STD DEV	2.689 nA	169.5 pA	101.5 mV	4.529 mV	20.57	12.33	3.629	.04346

* CATASTROPHIC REJECT(S) REMOVED AFTER THIS POINT.



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TABLE 7
FINAL DATA SUMMARY
SIDE A

PARAMETER	SPECIFICATIONS LIMIT		U N I T S	MEAN INT. DATA	AVERAGE Δ IN MEAN VALUE					
					POWER STRESS		TEMPERATURE STRESS I		TEMPERATURE STRESS II	
	RAYTHEON	MOTOROLA								
	MIN	MAX								
I _{CB0}	-	2	nA		-.12910	+.70597	+1.2608	+.10855	+2.1180	-.0038
V _{CE(SAT)}	-	1.2	V		+.02569	+.00072	+.21808	+.00577	-.00045	+.00081
h _{FE1}	30	90	-		+.85538	+1.3612	-8.2220	+1.1540	+6.5214	+5.4086

NOTE: Catastrophic reject(s) removed from data after final test point.

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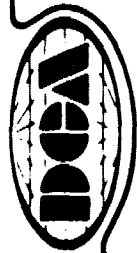
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TABLE 7
FINAL DATA SUMMARY
SIDE B

PARAMETER	SPECIFICATIONS LIMIT		U N I T S	MEAN INT. DATA	AVERAGE Δ IN MEAN VALUE					
					POWER STRESS		TEMPERATURE STRESS I		TEMPERATURE STRESS II	
	MIN	MAX					RAYTHEON	MOTOROLA	RAYTHEON	MOTOROLA
I _{CB0}	-	1	nA		-.17597	-.07857	+.38569	+.10868	+.59099	+.03650
V _{CE(SAT)}	-	1.2	V		+.02686	-.03368	+.10149	+.0062	+.007181	+.00161
h _{FE2}	3C	90	-		+.77115	+6.6792	-3.7540	+9.2910	+4.4229	+5.0786
h _{FE1} h _{FE2}	.9	1.1	-		+.08346	+2.0513	+.70355	-.16305	+.3803	+.00886

NOTE: Catastrophic reject(s) removed from data after final test point.

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JAN TX2N2060

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FAILURE SUMMARY

TABLE 8 STEP STRESS CATASTROPHIC

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	-	0	-
100 hr.	1	F	3	A
100 hr.	0	-	0	-
250 hr.	0	-	0	-
100% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
125% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
150% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	1	B
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
175% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	1	-

GROUP II 160 HR. TEMP. STEPS

TEST STEP (T _A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75°C	0	-	0	-
100°C	0	-	0	-
125°C	0	-	0	-
150°C	0	-	0	-
175°C	0	-	0	-
200°C	1	C	1	C
225°C	2	C	0	-
250°C	1	C	0	-
275°C	1	D	0	-
300°C	3	C	0	-

GROUP III 16 HR. TEMP. STEPS

TEST STEP (T _A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150°C	1	C	0	-
175°C	1	D	0	-
200°C	0	-	0	-
225°C	0	-	0	-
250°C	0	-	0	-
275°C	0	-	0	-
300°C	1	D	0	-

MFR "A" = RAYTHEON

MFR "B" = MOTOROLA

NOTES:

A $V_{CE} > 1.8V$ & $h_{FE} < 15$ B $I_{CB0} > 200nA$ C $h_{FE} < 15$ D $h_{FE}(\text{MATCHING}) > 1.65$ E $h_{FE}(\text{MATCHING}) < .45$

F Open (verified by failure analysis)

G Shorted (verified by failure analysis)

TABLE 9 STEP STRESS PARAMETRIC FAILURE SUMMARY JAN TX2N2060

GROUP I POWER STRESS				GROUP II 160 HR. TEMP. STEPS				GROUP III 16 HR. TEMP. STEPS			
TEST STEP	MFR A		MFR B	TEST STEP (T _A)	MFR A		MFR B	TEST STEP (T _A)	MFR A		MFR B
	QTY.	NOTE			QTY.	NOTE			QTY.	NOTE	
50% 50 hr.	1	A	13 B	75°C	0	-	14 A	150°C	3	A	1 B
100 hr.	1	B	0	100°C	0	-	0	175°C	1	A	0
100 hr.	0	-	0	125°C	2	C	0	200°C	1	A	2 B
250 hr.	0	-	0	150°C	1	A	1 C	225°C	1	C	1
100% 50 hr.	0	-	0	175°C	1	A	0	250°C	1	A	1 B
100 hr.	0	-	1 C	200°C	2	A	1 D	275°C	0	-	-
100 hr.	0	-	0	225°C	3	A	0	300°C	1	C	0
250 hr.	0	-	0	250°C	2	B	0				
125% 10 hr.	0	-	0	275°C	0	-	0				
15 hr.	0	-	0	300°C	1	E	0				
25 hr.	0	-	0								
100 hr.	0	-	0								
100 hr.	0	-	0								
250 hr.	0	-	1 C								
150% 10 hr.	0	-	0								
15 hr.	0	-	0								
25 hr.	0	-	0								
100 hr.	0	-	0								
100 hr.	0	-	0								
250 hr.	0	-	0								
175% 10 hr.	0	-	0								
15 hr.	0	-	0								
25 hr.	1	A	0								
100 hr.	0	-	0								
100 hr.	0	-	0								
250 hr.	1	B	1 D								

NOTES:

A h_{FE} (matching) minimum limit failureB h_{FE} (matching) maximum limit failureC I_{CBO} limit failureD h_{FE} maximum limit failureE h_{FE} minimum limit failure



JANTX2N2060

FAILURE ANALYSIS



FAILURE ANALYSIS
MSFC STEP-STRESS TEST
TRANSISTORS

JANTX2N2060

Date 16 September 1978

J/N 2CN242-38A P/N 2N2060 MFR RAYTHEON

FAILURE VERIFICATION:

S/N	BV _{CEO} -volts-	BV _{CBO} -volts-	I _{CBO} -uA- @ V _{CB} = 80 V	BV _{EBO} -volts-	h _{FE} @ I _C = 100 uA; V _{CE} = 5 V	V _{BE0} -volts- @ I _{BE0} = 10 mA	Initial Rej. @ Test Seq. No.:	Initial Rej. for:
900A	open	short	short	open	---	---	MP-3	Cat.
B	open	176	0.2 nA	open	---	V _{BC0} 0.69		
904A	open	open	---	---	---	---	MP-3	Cat.
B	0.20	0.20	10 mA*	short	---	V _{BC0} 0.70		

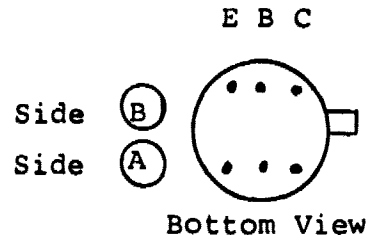
* Stopped at 3.2 V to prevent damage

INTERNAL VISUAL INSPECTION:

S/N 900 A, 900 B, and 904 A have open wires due to electrical overstress. (See Figures A-1 thru A-3.) All base and emitter gold ball bonds are surrounded with a narrow circle of "purple plague." S/N 904 A exhibits a hot spot surrounding the emitter wire bond. (See Figure A-4.)

CONCLUSION:

Both samples were destroyed by a fast rise (tens of microseconds) pulse of high current at normal voltage which melted the internal gold wires and shortened the junctions. The current level is estimated to be greater than 2 amperes



*h_{FE} trace present. Cannot meet stated test conditions. (Leaky)

**h_{FE} trace very leaky.

D = drift H = hysteresis Inv = inversion R = resistive S = soft Uns = unstable



FIGURE A-1

S/N 900A, Raytheon Sample, 86X

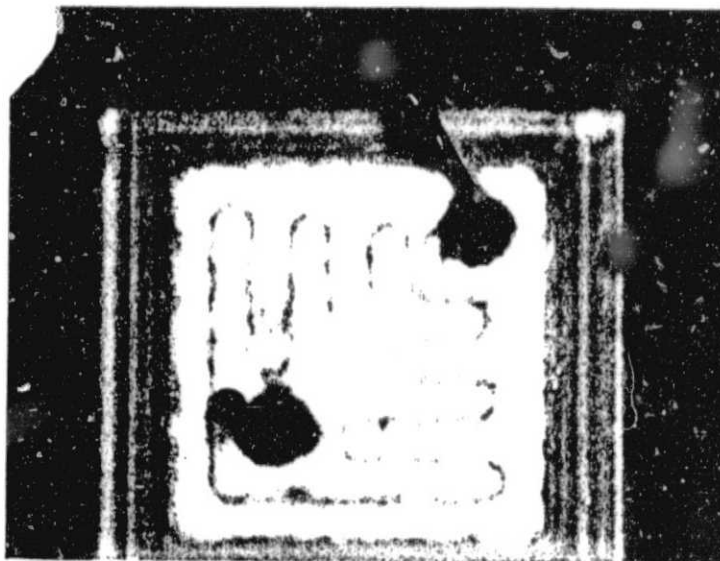
Open internal emitter wire due to electrical overstress.



FIGURE A-2

S/N 900B, Raytheon Sample, 86X

Open internal emitter wire due to electrical overstress.



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FIGURE A-3

S/N 904B, Raytheon Sample, 112X

Open internal base and emitter wires due to electrical overstress.

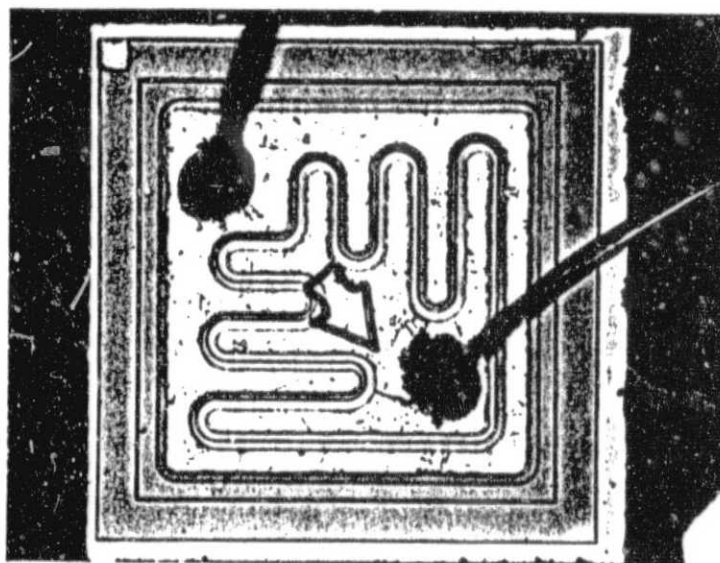


FIGURE A-4

S/N 904A, Raytheon Overall Die View, 112X

Arrow indicates area of melted emitter metallization due to electrical overstress. Note purple gold-aluminum intermetallics surrounding each ball bond.



JANTX2N2060

FAILURE ANALYSIS
MSFC STEP-STRESS TEST
TRANSISTORS

Date 16 September 1978

J/N 2CN242-38A P/N 2N2060

MFR MOTOROLA

FAILURE VERIFICATION:

S/N	BV_{CEO} -volts-	BV_{CBO} -volts-	I_{CBO} -uA- @ $V_{CB} = 80$ V	BV_{EBO} -volts-	h_{FE} @ $I_C = 100$ uA; $V_{CE} = 5$ V	V_{BEO} -volts- @ $I_{BEO} = 10$ mA	Initial Rej. @ Test Seq. No.:	Initial Rej. for
3705A	128	128	0.2nA	8.7	7.5	0.73	MP-1	h_{FE} match
B	130	130	0.6nA	8.7	7.4	0.74		
3708A	open	128	0.4nA	open	---	0.72	MP-1	h_{FE} match
B	106	128	0.2nA	8.7	44	0.75		

INTERNAL VISUAL INSPECTION:

S/N 3708A has an open internal emitter wire due to electrical overstress (See Figure A-6). There are no visual defects on S/N 3705 which relate to the present failure.

CONCLUSIONS:

S/N 3708 failed due to electrical overstress in the form of excess current at normal voltage. The destructive current had a fast rise time (tens of microseconds) and exceeded one ampere. S/N 3705 has experienced a decline in h_{FE} , while the collector-base leakage remains within specification limits. Such a loss of h_{FE} without any evidence of surface leakage or low breakdown voltage suggests a change in emitter efficiency. The migration of gold or other impurities possibly has continued under the influence of extreme high power operation with consequent loss of h_{FE} .

* h_{FE} trace present. Cannot meet stated test conditions. (Leaky)

** h_{FE} trace very leaky.

D = drift H = hysteresis Inv = inversion R = resistive S = soft Uns = unstable



FIGURE A-5
S/N 3705, Typical Motorola Die Layout, 36X

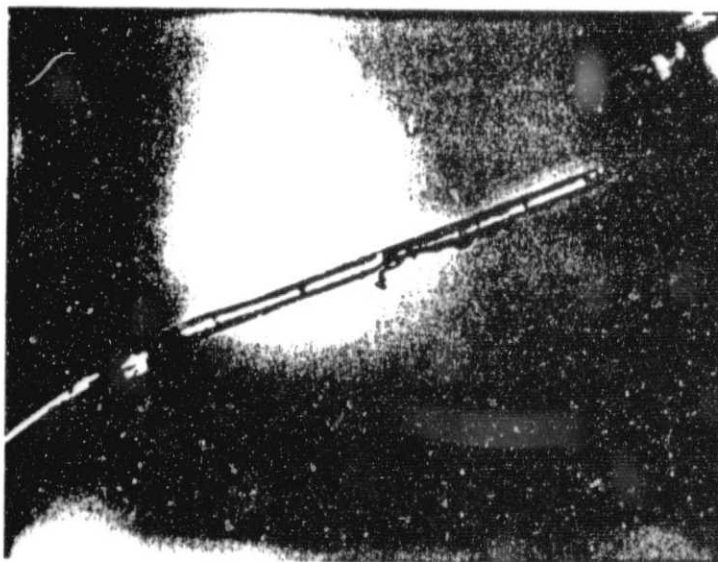


FIGURE A-6
S/N 3708A, Motorola Sample, 100X
Open internal emitter wire due to electrical overstress.



JANTX2N2060

FAILURE ANALYSIS
MSFC STEP-STRESS TEST
TRANSISTORS

Date 19 September 1978

J/N 2CN242-38B

P/N 2N2060

MFR RAYTHEON

FAILURE VERIFICATION:

S/N	BV_{CEO} -volts-	BV_{CBO} -volts-	I_{CBO} -uA- @ $V_{CB} =$ 80 V	BV_{EBO} -volts-	h_{FE} @ $I_C =$ 100 uA; $V_{CE} = 5$ V	V_{BE0} -volts- @ $I_{BE0} =$ 10 mA	Initial Rej. @ Test Seq. No.:	Initial Rej. for
1924A	110	164	18 nA	8.3	27	0.69	MP-9	h_{FE} match
B	85	160	17 nA	7.9	13	0.69		
1925A	160	170	26 nA	8.4	48	0.90	MP-7	h_{FE} match
B	100	160	20 nA	7.8	0.64	4.10*		
1916A	160	190	0.5 nA	8.6	15	0.71	MP-8	h_{FE} match
B	120	120	0.5 nA	8.6	13	0.72		
			* $V_{CBO} = 5.8$					

INTERNAL VISUAL INSPECTION:

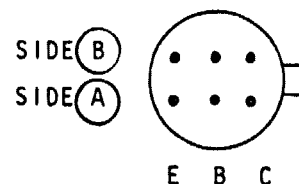
All three samples exhibited dark gold-aluminum intermetallics ("Purple Plague") around all gold ball bonds. (See Figure A-7.) The emitter wire of S/N 1924 (Side B) has been kinked and has a thin spot due to being stretched.

CONCLUSIONS:

All samples have experienced a marked loss of h_{FE} , and S/N 1925 (transistor B) has developed high contact resistance as evidenced by its excessive V_{BE0} and V_{BC0} (emitter and collector forward voltage drop).

There is no significant bulk or surface leakage on these parts. This implies that the h_{FE} fall-off is due only to a loss of emitter efficiency. The loss of injection efficiency in turn is due to the migration of gold and intermetallics under the influence of heat and bias, with a consequent loss of bulk lifetime.

BOTTOM VIEW

* h_{FE} trace present. Cannot meet stated test conditions. (Leaky)** h_{FE} trace very leaky.

D = drift H = hysteresis Inv = inversion R = resistive S = soft Uns = unstable

OF P. 10

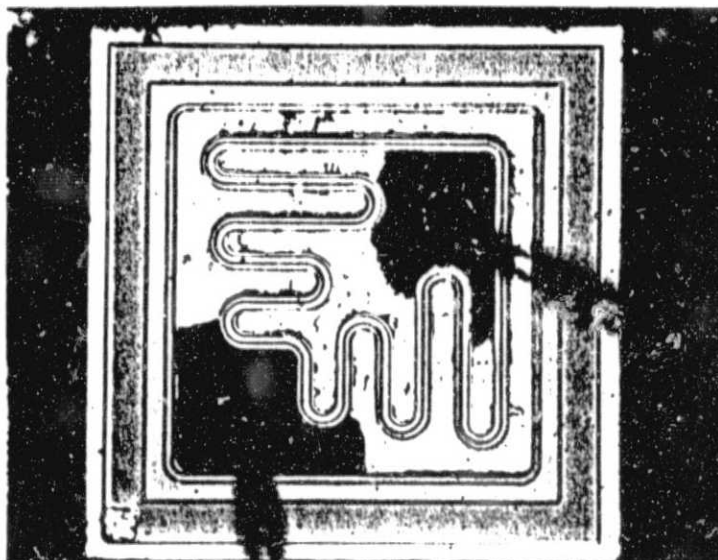


FIGURE A-7

S/N 1916, Typical Die Geometry of Raytheon Samples, 110X
The dark areas around the gold ball bonds are gold-aluminum intermetallics ("Purple Plague").